INTEGRATING VENUS PLANETARY SCIENCE INTO LIBERAL ARTS CURRICULA. Frederick Suppe,[1] Stephen D. Norton,[2] David Friedman,[3] Srinivas Kudaravalli,[3] and Christopher P. Stone,[4] [1]History & Philosophy of Science (CHPS)/Philosophy, 1102 Skinner, University of Maryland, College Park, MD 20742, and Geological Sciences, Indiana University, Bloomington, IN 47405 suppe@carnap.umd.edu; [2]CHPS/Philosophy, University of Maryland, College Park norton@carnap.umd.edu; [3]CHPS, University of Maryland, College Park; [4]Individualized Major Program, Indiana University.

Reports by the NRC, NAS, AAAS, NSF, and others have called for reinventing the American science curriculum in a manner that moves away from textbook science towards hands-on involvement with the actual doing of science. The goal is that students learn both substantive scientific content and come to understand how science works. Of particular concern is elevating the current dismal level of science literacy among the general American populace.

Planetary science is particularly well-suited as a focus of such science curriculum reform, especially since most of its data sets are archived on CD-ROM and available for classroom use and much of the actual science is done via computer modeling and thus requires no special laboratory equipment beyond typical university computer resources.

Efforts at the University of Maryland, College Park, to integrate Venus planetary science into the Liberal Arts Curriculum aimed at non-science majors are reported. Our basic strategy is to situate Venus science in historical context and then have students use special "tutorial" adaptations of research software with archived NASA data sets to replicate key developments in the history of Venus planetary science.

1. Efforts to Date

Our initial efforts involved development of historical materials (Suppe and Stone 1996) and demonstration lab modules that were tried out as units in a regular sophomore-level introductory philosophy of science course (http:// carnap.umd.edu:90/phil250/phil250.html). In Fall 1996 we offered an entire semester Venus version of that course built around the history of Venus exploration that used modeling practices in Venus science as a semester-long case-study evaluation of standard views in philosophy of science. Students did projects such as mapping portions of Venus at C1 MIDR resolution, finite-element modeling of subduction, and simulation modeling of Wetherill scenarios for evolution of potential impactors (http://carnap. umd.edu:90/ phil250/ Syllabus_250.html).

These efforts indicate that a one-semester course aimed at unselected lower-level undegraduate students reasonably can be expected to do real science with actual data sets or realistic simulations, while achieving a high level of understanding how science works. Students studied a range of practices such as modeling data by adding assumptions, end-member modeling, forward *vs.* inverse modeling, Monte Carlo simulations, raster *vs.* vector models, finite element modeling, parameterized boundary layer modeling, various image manipulation techniques, and stereo radar image analysis. They came to understand the significance of such notions as pixel resolution *vs.* resolution at which geological interpretations are reliable, similarity and differences between radar and optical images, admittance, emissivity, isostatic compensation, viscous relaxation of uncompensated structures, impactor fluxes, crater densities, resurfacing scenarios, volcanic eruption mechanisms, lava flow morphologies, and the significance of dimensionless quantities such a Rayleigh and Prandtl numbers in geophysical modeling,

Science content included basics of range and Doppler radar and their combined use in imaging, determination of Venus's axial rotational period, impactor processes, gravitational modeling and analysis, basic planetary model, harmonic representations of gravity and topography, phase diagrams, subduction, lithospheric heat transfer mechanisms such as hot spot volcanism, lithospheric conduction, and plate recycling. On the final examination students had enough sophistication to "Discuss the relations between dimensional analysis, fracticality, and scale invariance and the bearing these have on geophysical modeling" (http://carnap. umd.edu:90/phil 250/250_Solved_Final.html).

2. Work in Progress

Our goal is to develop a one-semester lab course for non-science majors built around replicating the scientific exploration of Venus. Instead of the traditional mix of text-book assignments, lectures, homework exercises, and scheduled lab sessions, these would be replaced by lab modules serving as the *primary vehicles* for teaching *substantive science content*. Students would spend 12 unscheduled hours a week doing Venus science, sometimes individually and sometimes collaboratively. The substantive content would be learned by doing lab with little advance outside preparation.

In one semester students would:

· Simulate Wetherill asteroid capture and orbital evolution models for potential impactors.
· Do Monte Carlo simulations to estimate Venus impactor flux for crater-age dating.
· Create 3-D surface perspective images of Venus's surface using Magellan topography and radar images.
· Learn to interpret radar images geologically.
· Use Geographical Information Systems (GIS) and SAR radar images to produce a collaborative geological C1 MIDR resolution mapping of the Venusian surface and an associated GIS data base.
· Use the GIS data base to investigate differential distribution of geological features on Venus's surface.
· Apply relative crater-age dating techniques to planetary surfaces.
· Use TECTON finite-element modeling to investigate possible subduction on Venus, corona formation, etc.
· Use NOAH to investigate various volcanic flow resurfacing models.
· Evaluate various planetary resurfacing models.
· Use Monte Carlo simulations to investigate compatibility of actual impact crater distributions on Venus with various resurfacing scenarios.

All these laboratories would be done using the actual NASA scientific data sets together with standard high-end scientific software adapted for course use via special user-friendly tutorial-like GUI "front-ends" that convert the software to sophisticated teaching instruments suitable for self-guided student lab use with virtually no learning curves. (Our basic design parameter is that the median time for students actually doing science the first time they use new software be under 10 minutes.)

Such a modeling approach requires that the geoscience content be approached mathematically. We are developing “Equation Explorers” that allow students to “see the science through the mathematics” by linking mathematical equations with simulation models where students can vary the values of variables in the equations and see the effects. The idea is to develop a “descriptive understanding” of the mathematics in a manner not tied to either systematic study of the mathematics or learning how to manipulate and solve the equations. (One might liken this to getting a reading knowledge of a language one can neither write nor speak.)

3. Demonstration Items

Our display will provide more detailed over-views of the curriculum development project and allow hands-on exploration of various sample lab modules and software developments. We expect to have the following available:

- A sample curriculum for the Venus lab course.
- A fully developed lab module on the geological interpretation of Magellan radar images. The lab is built around the supposed giant impact basins identified in 1972 Goldstone images (Rumsey, et al 1974; Schaber and Boyce 1977). Students have to find out what geological structures, if any, those large radar-dark patches were imaging (*Fig. 1*).
- Simulations of Wetherill scenarios (Wetherill 1977) for the evolution of Mars crossing asteroids from earth-crossers using *Gravitation Lt. 5.0.*
- Student vector mappings of C1-MIDR.60N125;1 and the associated data bases produced.
- A virtual reality tour of Meteor Crater, AZ, which illustrates impactor and ejecta processes (*Fig. 2*).
- An equation explorer for viscous relaxation of impact basins on Venus based on Solomon, Stephens, and Head 1982 and Solomon, Comer, and Head 1982.
- A new *tcl/tk* tutorial front-end for Jay Melosh’s TECTON finite-element modeling code (Melosh and Raefsky 1980) that enables students to explore subduction scenarios for Venus. It incorporates a new editor for TECTON that enhances its use as a planetary science research tool (Friedman & Suppe 1977).

References

D. Friedman and F. Suppe, “TECTON: Development of a *tcl/tk* front-end editor” LPSC XXVIII (Abstracts), 1977.

H. J. Melosh and A. Raefsky, “The dynamical origins of subduction zone topography,” *Geophys. J. R. Astron. Soc.* 60(1980): 333-354.

H. M. Rumsey, G. A. Morris, R. R. Green, and R. M. Goldstein, “A Radar Brightness and Altitude Image of a Portion of Venus,” *Icarus* 23(1974): 1-7.

G. G. Schaber and J. M. Boyce, “Probable distribution of large impact basins on Venus: Comparison with Mercury and the Mood,” pp. 603-612 in D. J. Roddy, R. O. Pepin, and R. B. Merrill (eds.), *Impact and Explosion Cratering* (New York: Pergamon, 1977)

S. Solomon, S. K. Stephens, and J. W. Head, “On Venus Impact Basins: Viscous Relaxation of Topographic Relief” JGR 87/B9(Sept. 10, 1982): 7763-7771.

S. C. Solomon, R. P. Comer, and J. W. Head, “The Evolution of Impact Basins: Viscous Relaxation of Topographic Relief,” JGR 87/B5(May 10, 1982): 3975-3992.

F. Suppe and C. P. Stone, *Venus Alive! Modeling Scientific Knowledge* draft manuscript issued in limited off-print edition UMCP Course Packet #168 (Beltsville, MD: BelJean, 1996) and on CD-ROM.

G. Wetherill, “Evolution of the earth’s planetesimal swarm subsequent to the formation of the earth and moon,” *Proceedings 8th Lunar Science Conference* (1977): 1-16

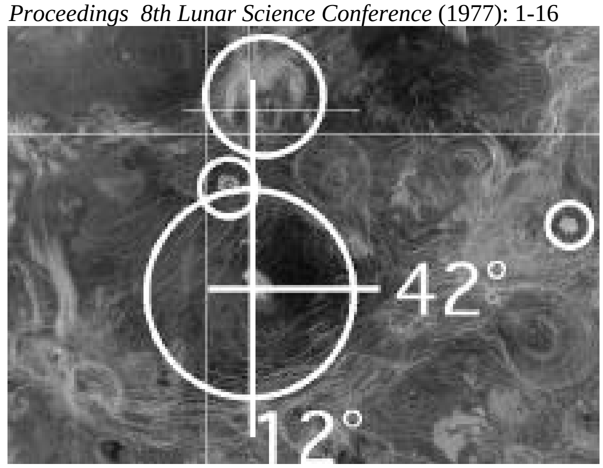

Fig. 1: Radar image interpretation lab module: Identification of nonexistent 540 km impact basin allegedly at 44N12. Audhumula Corona (45.5N12), Pritchard Crater (44N11.5) and Ruth Crater (43.29N20) also are circled.

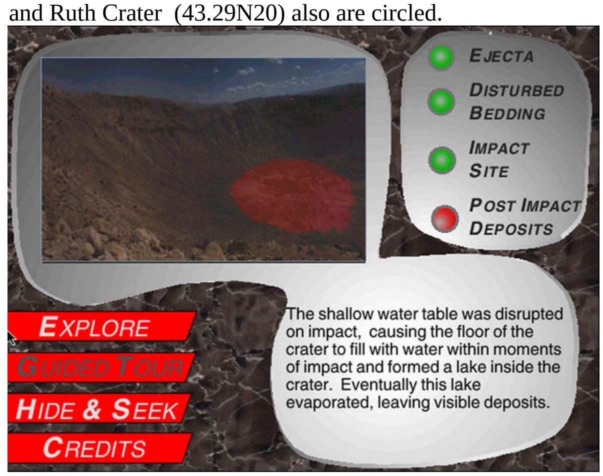

Fig. 2: Frame-grab of Meteor Crater Virtual Reality tour.

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